DOCKET NO. SA-510

EXHIBIT NO. 7A

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.

STRUCTURES GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

Cynthia L. Keegan

National Transportation Safety Board
Office of Aviation Safety
Washington, D.C.

December 13, 1994

STRUCTURES GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

A. ACCIDENT : DCA-94-MA-076

LOCATION : Aliquippa, PA
DATE : September 8, 1994
TIME : 1904 Eastern Daylight Time (EDT)
AIRCRAFT : Boeing 737-3B7, N513AU

B. STRUCTURES GROUP

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C. SUMMARY

On September 8, 1994, at 1904 Eastern daylight time USAir flight 427, a Boeing 737-3B7 (B737-300), N513AU, crashed while maneuvering to land at Pittsburgh International Airport, Pittsburgh, Pennsylvania. The airplane was being operated on an instrument flight rules (IFR) flight plan under the provisions of Title 14, Code of Federal Regulation (CFR), Part 121, on a regularly scheduled flight from O'Hare International Airport, Chicago, Illinois, to Pittsburgh. The airplane was destroyed by impact forces and fire near Aliquippa, Pennsylvania. All 132 on board the airplane were fatally injured.

The structures group convened on September 9, 1994, in Aliquippa, Pennsylvania to examine and document the airplane wreckage and wreckage path. The Structures Group was responsible for the accident scene and airplane structural documentation. After completing the on-site documentation on September 16, 1994, the airplane wreckage was moved to the USAir Alleghany International (AI) hangar on the east side of the Pittsburgh International Airport. A follow-up phase of the structures investigation was conducted between October 5th and 7th for further examination of the following areas: doors/door frames, wheels/tires, wheel well, floor beams, and leading edge slats/flaps. In addition, the Structures Group reconvened at the USAir AI hangar between October 30, and November 11, 1994 to reconstruct the following areas of the B737-300 airplane: the 178 forward pressure bulkhead floor beams, wheels and tires, wheel well, PATS auxiliary fuel tank, lateral control cables, and a black light inspection of selected areas of the airplane wreckage for possible evidence of bird debris. The documentation of this effort will be described in an addendum to this report.

Identifiable sections of the airplane wreckage were identified according to their structural location, and other smaller, unidentifiable pieces of the airplane were separated relative to their function on the airplane (i.e.; frames, stringers, floor beams, and pieces of airplane structure). A diagram detailing the on-scene wreckage documentation, and diagrams showing identifiable and relocated airplane structure are included as an exhibit to this report.

D. DETAILS OF THE INVESTIGATION

1.0 Wreckage and Impact Information

The primary point of impact occurred on an upsloping hillside on the south side of an access road surrounded by a forest of dense trees. The hillside location was determined by global positioning system (GPS) equipment to be 40° 36' 14.14" N latitude, and 80° 18' 36.95" W longitude, at an elevation of about 930 feet mean sea level (MSL). A ground scar was documented on top of the hill to the east of the main impact point and adjacent to the left wing. The ground scar measured approximately 25 feet long and was oriented along a magnetic heading of 285 degrees, as viewed inboard from the left wing tip. The outboard end of the ground scar contained several small pieces of red glass, with portions of the left wing tip located nearby. The ground scar, at a point 10 feet inboard from the end, measured approximately 2 feet wide and 14 inches deep. Trees surrounding the ground scar and the area where the left wing came to rest exhibited broken limbs and branches. The swath of trees and ground cover destroyed by the airplane impact is shown on the Wreckage Diagram included as an exhibit to this report. The U.S. Bureau of Mines utilized pulsed-based ground penetrating radar to assist members of the Structures Group in their search for buried wreckage. Subsequently, the primary point of impact and surrounding hillsides were excavated as much as 8 feet deep in search of buried wreckage. Pieces found buried beneath the left wing included a slat actuator, and pylon upper spar cap. Seat framing and the No. 2 engine generator were also found buried in the hillside near the main

impact.

1.1 WreckageDistribution

The left wing and No. 1 engine were located on top of the hill, south of the access road and east of the main impact area. The cockpit came to rest approximately 45 feet south of the main impact. Sections of cockpit window framing and cockpit wiring were found throughout the area, and one side of the twin nose wheel assembly was found adjacent to the area containing the cockpit wreckage. The left main landing gear drag strut and torque scissor link were found 45 feet east of the empennage, and the right main gear drag strut and torque scissor link were located underneath the empennage. Portions of the left and right main gear wheel and tire assemblies had separated from their respective landing gear assemblies and were located throughout the wreckage. The right wing also sustained severe impact damage and was located along the edge of the lower access road, approximately 50 feet west of the left wing,. The No. 2 engine separated from the right wing and was found abreast the access road approximately 30 feet west of the main impact. The empennage came to rest in the inverted position, about 20 feet west of the left wing. The horizontal stabilizers and elevators remained attached to the tail structure. The vertical stabilizer was separated from the empennage and lying on its left side with its upper leading edge parallel to the hillside upper slope, and the lower vertical fin adjacent to the horizontal stabilizers. Sections of fuselage were located throughout the accident site and exhibited severe impact damage. No other pronounced ground scar was documented except the ground scar created by the outboard left wing.

A section of the left outboard trailing edge flap was lying parallel to and north of the left wing ground scar. A section of the lower wing skin and front spar from the left wing were located on top of the ground scar. As a result of severe heat exposure from post impact fire, the lower wing skin and spar drooped over a portion of the No. 1 engine. A section of the left wing and left outboard trailing edge flap were lying perpendicularly across the wing ground scar. This section comprised of two portions; a 14-foot outboard portion (oriented leading-edge-down) and connected a 18-foot inboard portion (upright but oriented slightly leading-edge-down) containing the four outboard spoilers. The leading edge of the outboard portion was crushed in an aft and up direction. A leading edge slat actuator was found buried in the ground scar approximately 8 1/2 feet inboard from the end of the ground scar. The center of the left engine was located approximately 36 l/2 feet from the outboard end of the ground scar. A 3-foot section of the forward No. 1 engine pylon upper spar was found embedded about 2 l/2 feet in the left wing ground scar at an angle of approximately 75 degrees (relative to a horizontal plane). The section of upper spar exhibited compression damage to the upper spar cap and the aft half of the section was bent inboard.

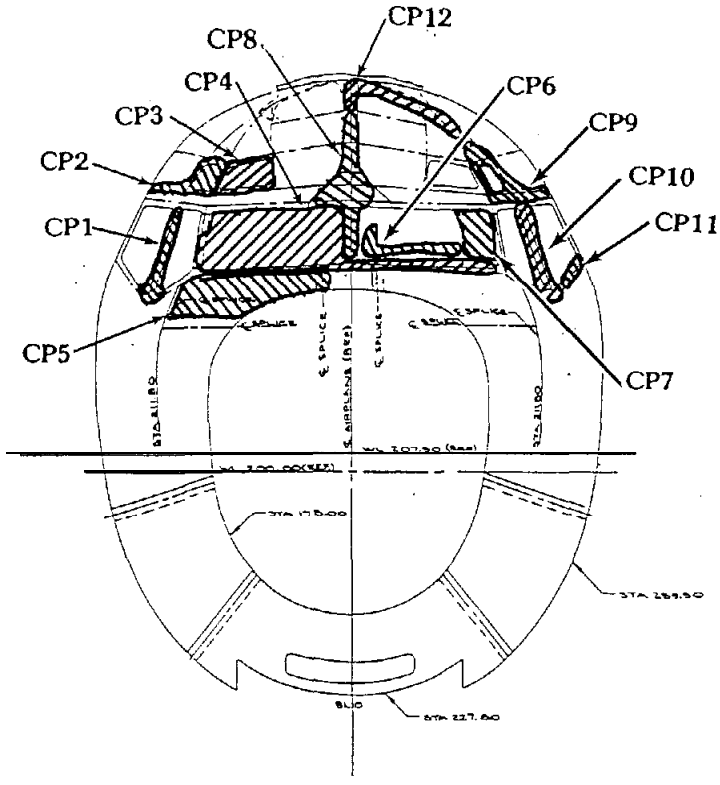
The No. 2 engine came to rest on the road below and west of the location of the main impact. Sections of the right wing were found on the north side of the access road and the adjacent hillside with the inboard section of the wing facing in the northeast direction. The vertical stabilizer upper leading edge came to rest along the top of the north hillside. The top of the rudder and vertical stabilizer were destroyed and exhibited impact damage. The lower portion of the vertical stabilizer came to rest next to the horizontal stabilizers, which were inverted on the north side of the road. The horizontal stabilizers remained attached to the tail structure and exhibited postimpact fire damage. The inboard portions of both horizontal stabilizer's leading edge was pushed aft and outboard.

Pieces of interior insulation and a passenger business card were located 2 l/2 miles east of the main wreckage site (downwind at the time of the accident), and exhibited soot and smoke damage. One witness who was at the Beaver Lakes Country Club at the time of the accident stated he heard the sound of the crash and two minutes later witnessed sooted insulation fall onto the golf course. The insulation, business card and sections of the airplane's cargo liner were sent to NTSB laboratories for examination, which revealed no evidence of explosives.

Recorded radar tracking data (TD) obtained from the Pittsburgh Terminal Radar Approach Control (TRACON) for USAir flight 427 was used to determine a ground area to search for airplane parts, had flight 427 shed parts in-flight prior to impact. Using the NTSB program WINDFALL, estimates of trajectory distances were made, using varied weights and sizes of assumed airplane pieces, to determine probable locations. For WINDFALL calculations a groundtack of 110 degrees, a groundspeed of 210 KIAS, and a flight track angle of zero degrees were used. The resultant trajectory distances were projected back along the flight path from the beginning of the airplane upset onto a topographical map that included the accident area On September 14, 1994, a search team of 140 volunteers, 20 Search Rescue, and Recovery Team (Rescue 40 SRRT), and NTSB personnel enmassed and ground searched the projected area where a sheded airplane part could have fallen. The search team spent several hours walking the search area. In addition, an aerial search of the accident airplane's flight path and the ground searched area was accomplished. No sections of airplane debris or structure were found that could have been attributed to USAir 427. The areas searched are crosshatched on a map included as an exhibit to this report.

2.0 Cockpit

The cockpit structure was severely fragmented. The following view of the cockpit structure shows the areas that were identified:



VIEW LOOKING AFT

Cockpit (CP) support posts CP-1, -10, and -11 exhibited compression damage along the posts. CP-2, -3, -4, and -5 exhibited compression damage surroundiig the window framing and also exhibited overload fractures at the forward and aft window posts, with a windshield wiper arm remaining attached to the CP-5 support and the CP-4 window attached and shattered. CP-6, -7, -9, and -12 sustained postimpact fire damage, and CP-8, -9, and -12 exhibited compression damage.

3.0 Fuselage

Sections of the fuselage were identified according to their structural station location and a fuselage diagram was utilized to document the identifiable pieces of the airplane. Approximately 50 percent of the fuselage skin panels between Body Station (BS) 259.5 and BS 1156 were placed in their structural location on the hangar floor. The majority of the skin panels had frame, stringer or intercostal structure attached to the skin panels. Each skin panel was documented, given an alphanumeric identifier, and subsequently identified outlined, and color coded on the fuselage reconstruction diagram. With regards to orientation of the airplane,

fuselage pieces to the right of the airplane centerline were labeled "RF", and pieces to the left were designated "LF". In general, the identifiable fuselage was severely deformed, however the outline of each structural piece shown on the diagram represents the non-deformed shape. Numerous pieces of the fuselage skin panels could not be identified because the pieces were either too small, due to impact fragmentation, or exhibited severe postimpact fire damage. As a result significant portions of the fuselage below the window belt (stringer 14) could not be identified. All fuselage fracture surfaces observed exhibited damage sustained at impact. No unrepaired structural anomalies were noted and no evidence of pre-impact fire was found.

The B737-300 fuselage is defined by specific body installations that include sections 41, 43, 46, and 48. The pieces in section 41 were extremely deformed along the airplane's longitudinal axis. This longitudinal compression and deformation resulted in crumpled and creased fuselage pieces. The majority of structure identified in section 41 was adjacent to doorways. In general, the fuselage structure in body sections 46 and 48 showed less longitudinal deformation than forward body sections 41 and 43. All fracture surfaces observed were consistent with damage sustained at impact.

3.1 Floor Beams

The floor beam structure was severely fragmented The largest piece of relatively intact structure was found just forward of BS 1016 and comprised portions of three floor beams located at BS's 986.5, 1006 and 1016. Other sections of identified floor beam structure consisted of a floor beam at BS 986, and aft of BS 727, in the G3 and G6 areas. No floor beam segments could be identified as components of any of the beams between BS 380 and BS 500. No cockpit seat tracks were located, however, two lavatory tiedowns, and two galley seat track mountings were identified. The largest pieces of seat track identified were from the wing box area. other sections of floor beams and seat tracks were too small to identify.

3.2 Wing Center Section (WCS)

The lower cap of the WCS front spar was fragmented cross-sectionally and exhibited distortion and bending of the spar cap. Approximately 40 percent of the in-spar lower cap was identified. Approximately five percent of the web was identified. About five percent of the front spar upper cap was identified with one piece measuring approximately 30 inches long x 12 inches wide. About five percent of the upper longitudinal floor beams were identified with the longest piece measuring approximately 36 inches long x 12 inches wide.

The upper panel of the WCS was approximately 25 percent identified with the largest piece measuring approximately 18 X 24 inches. About 10 percent of the lower panel was identified, and the largest piece measured 48 X 12 inches and was identified as a section of skin panel splice. All of the identified center section sringers exhibited overload spearation at the corner fillets. About 10 percent of both center section spanwise beam lower caps and webs were identified. The largest piece measured approximately 36 inches long by 12 inches wide.

The lower cap of the WCS rear wall was fragmented with the longest section measuring approximately 30 inches. The section was fractured longitudinally along the corner radius and consisted of approximately 75 percent of the total identifiable pieces of the rear spar lower cap. About 30 percent of the rear spar web was identified consisting of 12 pieces of different sizes, with the largest piece measuring 24 x 24 inches. The upper cap was fragmented similar to the lower cap, and consisted of approximately 40 percent identifiable structure. There was no evidence of pre-impact fire damage

3.3 Pressure Deck & Wheel Well

The pressure deck sustained severe fragmentation of the webbing and consisted of approximately two percent identifiable structure. The largest piece measured 21 inches laterally and 8 inches longitudinally and exhibited overload fractures. The BS 727 pressure bulkhead was also fragmented, with approximately 10 percent of the total structure identified. Several pieces of keel beam were identified, with the largest piece extending from BS 720 to 727A+5, and an intact section of splice identified at BS 727+16.

3.4 Side of Body Splice (BBL 70.85)

Approximately 50 percent of the rear spar terminal fittings were identified. The rear spar terminal fittings were attached to the spar or body at the body buttock line (BBL) 663 bulkhead frame and exhibited fractures along the vertical corner fillets. The lower splice plates exhibited cross-sectional fractures at three locations on both left and right sides. About 80 percent of the paddle fitting was identified and consisted of approximately 40 percent of intact paddle fittings with the remainig structure fractured at the stringer/paddle fitting joints. Approximately five percent of the upper splice double plus chord was identified and consisted of pieces of stringer, skin and chord joint, and exhibited cross-sectional fragmentation along the horizontal flange corner fillet radii. Approximately fifty percent of the front spar terminal fittings were identified and exhibited a fracture along the vertical corner fillets, common to the spars and rib web.

4.0 Doors

The following doors and door sections were identified and documented:

4.1 Forward Service Door

The forward service door was fractured into three sections exhibiting overload fractures and impact damage. The forward lower corner section measured 36 inches by 20 inches, and the upper section contained the torque tube and door opening mechanism and measured 24 X 30 inches. The lower aft section included the door cover and frame section. The handle and the handle pan (recessed area in door exterior) exhibited similar bending consistent with the handle in the latched position. The upper aft latch receiver, centering guide, and stop guide fitting directly below the centering guide were mounted on the aft body frame. Witness marks on these

components are consistent with an inward-downward motion of the door during separation. A notch in the lower guide arm plate was consistent with an inward motion of the guide arm from a closed door position. (Ref P/N 65-45871-523)

4.2 Forward Entry Door

The forward entry door sustained severe impact, postimpact fire damage, and soot damage to the skin and torque tube. A 16 x 9 inch section of outer skin contained a bent and cracked placard. The snubber was in a fully compressed position consistent with a closed door position. The aft segment of the lower gate was found embedded in the body aft frame. Three upper body stop fittings on the forward frame exhibited impact marks corresponding to the door stop fittings. The upper latch torque tube aft crank was fractured at the joint to the hatch torque tube. (Ref P/N GE-28925-69 rod assy.)

4.3 Lower Nose Compartment Access Door

Two segments of the body frame forward of the access door containing a mounted stop fitting were located. The center portion, however, which houses the locking pin was not identified. The exterior handle was bent inwards and pieces of wood were found embedded in both sides of the handle, and in the forward edge of the "push" button. The inside of the handle contained wood embedded in the right recessed area at the tapered end of the handle. No damage was found on the lower, forward edge of the handle (with the door fully closed, this portion of the handle is recessed into the handle pan; pushing the button on the outside of the handle allows the handle to pop out from the door).

4.4 E & E Compartment Door

The E & E compartment door separated into four pieces including the handle, opening mechanism a 9 x 9 inch section of door skin with placard, and a 9 x 4 inch section of the skin and frame. The section of skin and frame contained the door latch with the latching pin in the down and latched position, and remnants of the exterior handle exhibit alignment of the handle within the handle pan as in a stowed position.

4.5 Forward Cargo Door

The forward cargo door was destroyed except for the door handle, door stop, the door torque tube (containing the latch roller on the end), and the door snubber. The snubber was frozen in an extended position and bent slightly. The snubber piston rod was fractured near the threads of the rod end, approximately 3 inches from the base of the snubber (i.e., where the piston moves in and out of the snubber). The shinier portion of the piston measured

approximately 1 l/2 inches from the base of the snubber.[1] The latch receiver and adjacent stop fitting mounted on the aft body frame, both showed impact witness marks consistent with an inward movement of the door at separation. (Ref P/N 103661999)

4.6 Right Overwing Exit Door

The right overwing exit door exhibited impact damage on the outer structural framing, and the interior plastic panel and window were destroyed. The mechanism and latches were intact and a stop and a 16 inch section on the forward edge were destroyed. Witness marks on the forward latch receiver were consistent with an inboard door motion during separation. (Ref P/N 50-7978-97)

4.7 Left Overwing Exit Door

The left overwing exit door was separated from the corner of the window to the upper aft corner. The inside egress handle was attached and exhibited severe impact damage. No corresponding fuselage components were located.

4.8 Aft Entry Door

The aft entry door sustained impact damage to the outer skin and top forward corner, however, the aft door stops and latches were intact. The aft, upper latch torque tube receiver and the upper two body stops exhibit an inward downward motion of the door, from a closed position. Two body stop fittings above the lower hinge on the forward frame contained witness marks and thread imprints from the door stop pins. The witness marks were consistent with an inward-upward motion of the door, at impact, from a door-closed position. The corresponding two door stop pins were sheared off, and the upper, forward latch crank was sheared off at the joint to the latch torque tube. Four lower stops remained attached to the forward side of the door.

4.9 Aft Galley Service Door

The aft galley service door sustained impact damage on the outer skin door and separation of the door 24 inches from the bottom. The door stops and latching mechanism were intact and the interior door panel was destroyed. Scrape marks on the exterior handle and surrounding structure were continuous and aligned. Witness marks on the aft body stop fittings were consistent with contact by the door stop pins. Witness marks on the forward body stop fittings were consistent with an inboard-forward motion of the door during separation.

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[1]Documentation of a forward cargo door snubber on the closed door of a B737-200 indicated 1 5/8" of piston travel (shiny portion) and 5 l/2" from the base of the snubber to the center of the rod end eyebolt. The B737-200 forward cargo door design is the same as the B737-300 forward cargo door.

4.10 Aft Cargo Door

The lower half of the aft cargo door adjacent to the top of the torque tube was separated and sustained impact damage. The torque tube, latches and handle remained intact, however, the center section of the door was destroyed. The upper forward section of the door separated, with the hinge and stops attached. The outer framing and skin also sustained impact and compression damage. The snubber was frozen in an extended position and bent slightly. The shinier portion of the piston measured approximately 1 l/8 inches from the base of the snubber. The exterior handle and the handle pan were bent and exhibited alignment of the handle with the handle pan. A body-mounted stop fitting on the forward frame contained a gouge with thread indentation marks consistent with the threads of the door stop pin.

4.11 APU Door

The APU door frame was intact on the left side of the fuselage and exhibited impact damage from BS 1156 forward to BS 1088. The frame sustained impact damage from BS 1156 to BS 1016. The stabilizer frame separated from the empennage at BS 1121, and exhibited fractures and impact damage.

5.0 Wings

Sections of the wings were located with the wing sections placed in their relative position with respect to the fuselage. The wing center section and the rib section at BBL 70.85, including the upper and lower splices, were severely fragmented but exhibited no fire damage. All the lower splice and terminals were identified and located. Pieces of the upper splice, upper and lower panels, front and rear spars, and webs of the rib and spanwise beams were collected and reassembled. Approximately 60 percent of the center section wing structure was identified and relocated.

The left and right rear spars of the outboard wing were 100 percent relocated from segments. The left and right front spars of the outboard wing were 90 percent reconstructed from available segments. A large section of the left wing was intact, from the tip closure rib to wing station (WS) 505, and two large portions were separated spanwise from WS 505 to the nacelle area, at approximately wing buttock line (WBL) 157. From WBL 157 inboard, the wing was severely fragmented, and contained evidence of severe postimpact fire damage in the area of the nacelle. A 12 foot span of burned area was located on the aft and inboard area of the left wing. A large section of the left aft wing tip was recovered. In addition, a crushed portion of the left forward wing tip, which had enclosed the red wing tip lens, was identified.

The largest piece of inspar structure on the right wing was about 1 l/2 foot wide and was attached to the rear spar from WS 583 inboard to WBL 355. The remaining portions of inspar structure were fragmented. The wing structure at WBL 135, and outboard exhibited severe fire

damage. Both fuel filler caps for the left and right fuel tanks were found in their respective locations. A on-by-two foot aft outboard portion of the right tip was the largest section identified. Examination of the left and right inspar wing structure revealed no evidence of in-flight fire or pre-impact structural failure.

The upper panel of the wing center section was approximately 25 percent identifiable with the largest piece measuring approximately 18 x 24 inches. About 10 percent of the lower panel was identified, and the largest piece measured 48 x 12 inches and was identified as a section of skin panel splice. All of the identified center section stringers and "Z" section stringers exhibited overload separation at the corner fillets. About 10 percent of the center section span wise beams (number 1 and 2) lower cap and web were identified. The longest piece measured approximately 36 inches long x 12 inches wide. No indication of fatigue or corrosion were observed throughout the wings or their control surfaces.

5.1 Leading Edge and Krueger Flaps

About 5 percent of the inboard leading edge of both wing structure, located above the Krueger flaps from the nacelle to the side of the body, were identified. The Krueger flaps from both wings exhibited severe fragmentation. Many portions of the torque tube and flap nose and all actuator attach locations were identified. The fixed leading edge, outboard of the nacelle, on both wings was destroyed, exposing the interior ribs, and exhibited post-impact fire damage on the right wing. The slats were crushed and segmented and also exhibited postimpact fire damage.

5.2 Leading Edge Slats

The No. 1 outboard slat remained partially attached to the front spar of the left wing. The inboard main track is intact, and in the fully extended position with the anti-rotation feature intact. The outboard main track was fractured at the forward end of the track and at the forward rollers of the roller rib. The slat track was in the fully extended position. Both track fractures were examined by a NTSB metallurgist and exhibited overstress fractures (See the NTSB metallurgy report included as an exhibit to this report). The outboard auxiliary arms remained attached to the front spar and are in the extended position. The inboard arm was detached at the auxiliary track.

Slat No. 2 remained attached to the front spar at both the inboard and outboard main tracks and through the outboard auxiliary arm and track. The main tracks were in the fully extended position with the anti-rotation features intact. The inboard auxiliary track exhibited an overload fracture and the bolts that hold the auxiliary arm to the slat were fractured. All of the No. 2 tracks and arms were bent, displacing the slats in the outboard direction relative to the left wing.

The No. 3 slat was partially connected to the front spar with sections of the spar and slat skin destroyed. The outboard main track remained attached to the front spar in the fully extended position with the anti-rotation feature intact. The inboard main track was also fully extended;

however, the main track bolt was fractured at the rib attachment exhibiting overload fractures. The inboard auxiliary arm and inboard auxiliary track exhibited an overload fracture and the auxiliary arm was separated from the slat ribs because of fractured rib attach bolts. The outboard auxiliary track also exhibited overload fractures of the auxiliary track, and the auxiliary arm was found in the fully extended position.

Slat No. 4 sustained severe impact damage to the leading edge and separation of the main and auxiliary tracks from the front spar. The outboard main track exhibited an overload fixture at the track aft end of the track downstop bolt. The track was found in the fully extended position, and remained attached to the slat ribs with the anti-rotation feature intact. The inboard main track exhibited an overload fracture nine inches from the downstop end, and the forward track segment remained attached to the slat ribs with the anti-rotation feature intact. The outboard auxiliary arm was fractured and the inboard aux arm was separated from the slat ribs and jammed inside the auxiliary track in the intermediate position (resting in the detent).

The No. 5 slat remained attached to the leading edge spar at the inboard and outboard main tracks. Both main tracks remained attached at the slat ribs with the anti-rotation feature intact. The outboard main track was in the fully extended position, and the inboard main track was jammed in the nearly retracted position with caked mud and dirt impacted in and around the track and roller ribs. Both auxiliary tracks exhibited overload fractures of the tracks and the tracks were bent in the outboard direction relative to the right wing tip.

Slat No. 6 sustained severe impact damage to the leading edge and separation of the main and aux tracks from the leading edge spar. The outboard main track was fractured into several pieces and separated from the roller ribs. The inboard main track exhibited an overload fracture of the down stop and separation from the roller ribs. Both main tracks were attached to slat ribs with anti-rotation features intact. The two outboard auxiliary tracks were fractured at the forward supports, and the inboard track auxiliary arm was attached, however, the slat ribs were detached. The inboard auxiliary arm was located between the intermediate and full extend position and the center auxiliary arm was in the full extended position.

5.3 Flaps and Flap Tracks

The left wing outboard flaps were located. The flaps exhibited compression damage and postimpact fire damage to the inboard ends. The fore flap fractured in two pieces with severe damage to the inboard end. Each of the outboard flaps (fore, mid and aft) on the right wing were fractured into three large segments and exhibited severe postimpact fire damage. The left wing inboard flaps were identified and exhibited fracturing of each flap in two halves with severe post-impact fire damage to the inboard three quarters. Each of the right wing inboard flaps were fractured in two pieces. The outboard section of the right wing fore flap was fractured and exhibited compression and postimpact fire damage. All four exhaust gates were located in their respective positions and exhibited overload separation at the attachment locations. The flap tracks were also reconstructed at their respective wing locations. There was no evidence found of structural fatigue or pre-impact fire to the flaps or flap tracks.

5.4 Ailerons and Balance Tabs

Approximately 80 percent of the left wing aileron and balance tab was located. The relocated left wing aileron exhibited severe impact damage. The majority of the right wing aileron was destroyed with approximately 20 percent of the structure identified and reconstructed. Fourteen balance weights were identified for the right aileron and 11 weights were identified for the left aileron.

5.5 Spoilers

The left wing outboard spoilers remained attached to the rear spar at their respective locations. The number 1 spoiler was fractured into two pieces and the number 2 and 3 spoilers exhibited postimpact fire damage. The left wing inboard spoiler exhibited severe postimpact fire damage and was also fractured into two pieces, with the remnants of burnt structure attached to the actuators. The right wing outboard spoilers remained attached to the rear spar and exhibited severe postimpact fire damage. One third of the number 5, right wing inboard spoiler was attached to a large triangular shaped trailing edge panel, and exhibited post-impact fire damage.

5.6 Landing Gear Beams

Both landing gear beams were fractured at their rear spar attachments, exhibiting overload separations. The inboard end of the swing linkages were still attached and contained portions of the fuselage skin.

6.0 Landing Gear

6.1 Nose Gear

The twin nose wheel assemblies and steering cylinders were fractured from the shock strut. The nose gear upper torsion link and steering collar was fractured at the attachment to the shock strut outer cylinder. The cylinder was extended six inches. The upper drag brace, lower drag brace link and nose gear actuator were separated from the lower drag brace and the actuator was extended eight inches. One of the nose gear tires separated from the wheel and exhibited burnt and melted rubber around the tire tread and steel bead wires were exposed. The other tire remained installed on the wheel with the tire deflated, torn and burnt.

6.2 Left Main Gear

The left main gear separated at the shock strut outer cylinder adjacent to the side strut attachments. The shock strut inner cylinder remained integral to the axle and the twin wheel assemblies. The left inboard wheel rim was fractured into at least six pieces; all fracture surfaces were the result of overload. The side strut and drag strut remained attached and intact and

exhibited heavy sooting. The walking beam was attached to the upper side of the forward trunnion; however, the forward trunnion arm was fractured ten inches from the bearing and exhibited an overload fracture. The aft trunnion was intact and exhibited abrasion to the trunnion teeth.

Left Outboard

wheel:	Boeing P/N 3-1439-6, S/N 6679 (BFG)
Tire:	H40x14.5-19 (26 ply)

The tiebolts and outboard flange of the wheel were intact, but bent in several locations. The inboard flange contained a 6 inch section of fractured surface that exhibited characteristics of tensile overload separation. The partially destroyed tire remained on the wheel, and exhibited heavy postimpact fire damage. The wheel, tire, and brakes also exhibited fire damage, and the wheel over-inflation plug was ruptured.

Left Inboard

wheel:	Boeing P/N 3-1439-3, S/N 4633 (BFG)
Tire:	not recovered[2]

The outboard wheel half was broken into many pieces; the sections found measured 6-9 inches. The wheel sections and the arc of the flange/tube well exhibited no fatigue characteristics on fracture surfaces. Thirteen of the tiebolts were installed, and intact, and three tiebolts were fractured near the first thread (and bent and necked down). The tiebolt fracture surfaces were typical of tensile overload. All fuse plugs were intact, and the overinflation plug was intact, with no evidence of fire damage to the wheel or brakes. The exterior cavities on the wheel and brake were heavily impacted with dirt. The axle grease exhibited no indications of overheating, and several gouges were present on the rim and wheel flange.

6.3 Right Main Gear

The right main gear lower shock strut inner cylinder, axle, twin wheel and tires were integral and the inner cylinder was separated from the outer cylinder. The shock strut outer cylinder was fractured four inches above the attachment of the side strut lower brace, exhibiting an overload fracture and a spiral crack extending vertically through the section of outer cylinder. The right main gear side strut and drag strut were attached and intact, and the downlock bungees were found attached to the reaction link and uplock spring. The aft trunnion was fractured and exhibited severe forward loading and twisting. The forward trunnion and trunnion arm were fractured and the inboard arm assembly exhibited signatures of overload fracture.

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[2]The left inboard tire was located on November 1, 1994 and will be documented in an Adendum report.

Right Inboard
wheel: Boeing P/N 3-1439-2, S/N 393 (BFG)
Tire: H40x14.5-19 (26 ply)

The inboard right tire remained on the wheel, but had multiple abrasions and cuts to the rubber and tread. All tiebolts were installed and intact. The wheel flange was intact, and there was no fire damage to the tire, wheel, or brakes. The overinflation plug was not ruptured, and the fuse plugs were intact. The axe1 nut for the right inboard wheel was fractured.

Right Outboard
wheel: Boeing P/N 3-1398-1[3], S/N 405 (BFG)
Tire: H40x14.5-19 (26 ply)

The right outboard tire was separated from the wheel, and a 6 x 12 inch oval chunk had separated from the center tread. There was no fire damage to the wheel, tire, or brakes, and all fuse plugs were intact. The outboard wheel half contained a few gouges in the rim and was broken in multiple pieces, and exhibited no indications of fatigue. Fourteen tiebolts were intact, and 2 tiebolts were fractured, typical of tensile overload. The overinflation plug was ruptured and all fuse plugs were intact.

7.0 Empennage

7.1 Vertical Stabilizer and Rudder

The vertical fin and rudder sustained fire and impact damage. The dorsal fin was destroyed and the leading edge of the vertical stabilizer skin was destroyed and the exposed vertical webs were crushed in the upward and aft direction. The vertical stabilizer aft of the rear spar sustained fire damage, and postimpact fire consumed an area 11 feet long by 4 foot deep, 6 1/2 feet from the base of the vertical stabilizer. The burned away area exposed the balance weight supports and the edges of the burned composite structure were shredded and torn. The rudder also exhibited an area of burned and missing structure extending 10 feet 3 inches long, 6 l/2 feet from the base of the rudder hinge. The upper cap of the vertical tail remained intact.

7.2 Right Horizontal Stabilizer

The entire leading edge of the right horizontal stabilizer exhibited compression and crushing in the aft direction. Four feet of the inboard leading edge of the horizontal stabilizer was destroyed and crushed in the aft direction exposing the internal spars and ribs. The outboard trailing edge exhibits heat and postimpact fire damage throughout a three foot section adjacent

[3]The 3-1398 series wheel has been certified by Boeing as being intermixable with the 3-1439 series wheel on B737-300 airplanes.

to the elevator. The elevator exhibits severe fire damage and shredding of the burnt composite material from the outboard end to 11 feet inboard. An 8 x 2 foot section of the right horizontal stabilizer and elevator were destroyed by fire.[4] The inboard eight feet of the elevator exhibited cracks in the upper elevator surface.

7.3 Left Horizontal Stabilizer

The entire leading edge of the left horizontal stabilizer exhibited compression and crushing in the aft direction. Five feet of the leading outboard section of the stabilizer was destroyed, with the remaining stabilizer exhibiting compression damage in the aft direction. The inboard seven feet of stabilizer (adjacent to the APU access door) is crushed five feet in the aft direction exposing the internal spars and ribs.

7.4 Left and Right Elevators

Both elevators were attached at the left and right stabilizers and continuity was established. The tab rods were connected and operated in accordance with proper operation (i.e.: elevator "up"/tab "down"). The left hand stabilizer and elevator remained attached to the tail section. The elevator balance weight was attached at the outboard end of the left elevator. Two of the elevator neutral shift rods were attached to the stabilizer and the elevator centering unit The right elevator was attached to the stabilizer, and the outboard elevator balance weight was attached. The left elevator was fractured at two locations; three feet and nine and a half feet from the outboard end. The elevator was bent downward and exhibited burn damage. The bottom surface of the inboard left elevator exhibited a 1.5 square foot section that showed evidence of heat and postimpact fire damage.

8.0 Control Cables

8.1 Left Wing Spoiler Cables

The left wing spoiler cables were attached to the No. 2 and No. 3 spoiler input quadrants and were identified as wing spoiler (WS), WSA1, WSA2, WSB1, and WSB2. All cables were visually inspected with 10 power magnification. All cable damage appeared to be tensile overload. The cables fractured outboard of the midspan turnbuckles. There were no spoiler cables identified inboard of the fixtures leading to the wheel well. WSA2 was broken 45 inches inboard, and WSA1 was broken 35 inches inboard of the No. 3 spoiler quadrant. WSB1 was broken 40 inches inboard of the No. 2 spoiler quadrant. WSB2 measured 130 inches between fractured ends.

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4 Reference the attached diagram showing post fire and impact damage to the vertical horizontal stabilizers.

8.2 Left Wing Aileron Bus Cables

The outboard aileron bus (ABS) A and B cables were found attached to the aileron quadrant and turnaround pulley. The ABSA cable was broken approximately 13 feet outboard from the turnbuckle and the ABSB cable was broken about 2 feet from the turnbuckle. The ABSA cable measured 359 inches to the fractured end, 27.2 inches shorter than the manufactured length of 382.2 inches. The ABSA cable exhibited some wires fractured 16 inches from the broken end. The ABSB cable measured 291.5 inches from the fractured end, 156.7 inches shorter than the original blueprint length of 448.2 inches. The separation of this cable was near a pulley at wing station 259 and exhibited a tensile overload fracture similar to the ABSA cable. An unidentified small cable portion (of about 8 inches) was found attached to a broken section of the aileron PCU output quadrant. The inboard ABSA and ABSB cables and associated turnbuckles were not identified during this phase of the investigation therefore, the left aileron position at impact could not be determined by cable positions.

8.3 Right Wing Spoiler Cables

The outboard spoiler cables were attached to the No. 6 and No. 7 spoiler input quadrants and identified as wing spoiler (WS) Al, B1, A2, and B2. WSA2 measured 4 feet 2 inches inboard from the number 6 spoiler input quadrant and WSB2 measured 5 feet 9 inches from the quadrant at the point of separation. WSA1 fractured 8 feet 3 inches inboard from the No.7 spoiler input quadrant and WSB1 fractured at the inboard turnbuckle. All cables exhibited fractures due to tensile overload, and the inboard spoiler cables were not identified.

8.4 Right Wing Aileron Bus Cables

Both outboard aileron bus cables were found inside the outboard wing area, and the ABSA cable was attached to the outboard aileron quadrant and the turnaround pulley (the pulley was destroyed). The ABSA cable was fractured four feet from the inboard end close to the inboard pulley and 29.4 inches were not identified The total ABSB cable measured its total manufactured length and it was fractured at both the inboard turnbuckle and cut in two at the accident site. The fractures were consistent with tensile overload.

The aileron bus cables were measured to determine if aileron positions could be established at impact. The two ABSA cables were located except for a 29.4 inch section just inboard of the body/wing pulley. A permanent set on the outboard ABSA cable near this pulley (equivalent to approximately a 30 degrees clockwise control wheel position from neutral) revealed the right aileron was in the up position. A pinched area exhibiting internal wire breakage was noted 84 inches outboard of the body/wing pulley. Another permanent set was found at about the wing station 465 pulley.

The ABSB cable run also contained two cables; however, the inboard ABSB cable attached to the PCU output quadrant was not identified. The outboard ABSB cable was cut in

two pieces during wreckage recovery; the cable measured correct blueprint length when the cut ends where joined. A pinched area was found 1 l/2 feet outboard from the body/wing pulley. In addition, an area of split and separated cable strands were located 12 feet outboard of the body/wing pulley on the ABSB cable.

8.5 Unidentifiable Cables

Four bins containing cable remains were visually inspected at all broken ends with ten power magnification to determine method of failure. All were considered broken due to tensile overload. Several cables were sent to NTSB Materials Laboratory for further examination and to verify conclusions from the visual inspection.

Elevator cables at the tail section were inspected and exhibited fractures due to tensile overload. Cables attached to two structural pieces of tail section were also inspected with the same results; i.e. tensile overload. Other miscellaneous cables found among the debris were inspected and exhibited tensile overload fractures.

9.0 Fire

9.1 Wheel well

There was no evidence of pre-impact fire damage. The fracture surfaces examined were covered with soot, and the fractured sections exhibited discontinuity of the sooted and unsooted areas. The landing gear surfaces were examined to determine whether a tire fire, or fire from another source, had occurred prior to impact; no evidence of pre-impact fire was found.

9.2 Main Landing Gear

There was no evidence of pre-impact fire damage on the landing gear strut or on any of the wheels or tires. There was no sooting or other evidence of pre-impact fire in the vicinity of the bottom of the landing gear struts. Samples were taken of materials deposited on the rim of the left inboard wheel for chemical analysis to determine source of material. The left inboard and outboard tires and left outboard wheel exhibited evidence of postimpact fire damage. The left outboard tire was attached to the wheel, but had been heavily burned.

9.3 Forward and Aft Cargo Compartments

A section of aluminum flooring from the forward cargo compartment was examined. There was some sooting on the underside of the floor consistent with postimpact fire damage. The upper surface of the floor showed no evidence of fire. Neither of the two cargo compartment pressure relief/emergency access panels, which form a section of the cargo compartment ceiling liner in the forward and aft compartment, exhibited fire damage on either side. There was no evidence of fire or soot on the aft cargo door, nor was there evidence of fire

damage found on the recovered pieces of the forward cargo door. Pieces of cargo compartment liner were identified, and exhibited evidence of smoke and fire damage consistent with postimpact fire. In addition, the forward outflow valve (or cargo heat valve) exhibited no evidence of soot deposits.[5]

9.4 Cockpit and Passenger Compartments

The identifiable sections of passenger cabin and cockpit structure exhibited no evidence of pre-impact fire. There was no evidence of streaking of burned or sooted structure on the interior or exterior surfaces of cabin and cockpit materials.

10.0 PATS Auxiliary Fuel Tank

The accident airplane incorporated a PATS, Inc. auxiliary fuel tank system. The 425 gallon fuel tank was located in the forward end of the aft cargo compartment and was designed to withstand cabin pressure without collapsing or rupturing. Leakage at any location in the tank is ported overboard at the drain mast. Additionally, when cabin pressure exceeds 1.5 psi above ambient air vent valves close. In addition, at any positive delta P cabin air enters the dry bay and tank core and purges any fuel or condensation through the drain mast. Fuel in the tank is transferred to the wing center tank using cabin or bleed air pressure. To protect the tank from over pressurization, a safety pressure relief valve is utilized. The relief valve is designed to automatically open into the center tank if the tank's internal pressure exceeds ambient by 10 psi. Maintenance records indicated that the PATS auxiliary fuel tank was installed in N513AU on October 17, 1987 and was deactivated on January 10, 1994.

Pieces of the PATS auxiliary fuel tank were examined. Some of the fragments exhibited fire damage; however, the fire patterns on various pieces were random. There was no evidence preimpact fire such as a continuous burned pattern on pieces that had been together before the final impact. The discontinuities of tire damage throughout the structure was consistent with postcrash fire.

Cynthia L. Keegan
Structures Croup Chairman

for JACK DRAKE
12-14-94

[5]The air that flows through the forward outflow valve originates in the cockpit, where it flows into the electronics bay compartment and then around the forward cargo compartment to warm the interior of the compartment, and then through the valve and overboard.